#2433

Biological Evaluation

(TP-R10-43)

Spruce Beetle Activity—Lake Clark National Park

December 1993

BIOLOGICAL EVALUATION R10-TP-43

SPRUCE BEETLE ACTIVITY -- LAKE CLARK NATIONAL PARK

DECEMBER 1993

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INTRODUCTION

The most destructive insect of Alaska's spruce forests is the spruce bark beetle, Dendroctonus rufipennis (Kirby). This insect has killed mature spruce on more than 2,000,000 acres of Alaska's forested lands since the 1920's (Holsten 1990, Werner et. al 1977). Spruce beetle infestations cause extensive tree mortality and modify stand structure by reducing average tree diameter, height, and stand density leaving small, slow-growing trees and intermediate-sized trees to become dominant (Holsten et al. 1991).

The spruce beetle infests all species of spruce within its geographic range which extends from Alaska to Arizona and throughout northeastern United States (App. A). All species of Alaska spruce are susceptible to beetle attack, but black spruce (Picea mariana) is rarely attacked. Most spruce beetle infestations have occurred in the Lutz (P.x lutzii) and white spruce (P. glauca) stands of south-central Alaska where northern conditions appear to be more favorable for increases in populations of spruce beetles (Holsten 1990).

Alaska spruce bark beetle populations increased dramatically for the third consecutive year in 1992 (USDA 1993). Active on-going and newly detected infestations now cover more than 600,000 acres; an increase of more than 200,000 acres over levels infested in 1991. More than 90% of this bark beetle activity is occurring in south-central and interior Alaska.

Many areas of Alaskan forests have been repeatedly infested over the years: Eklutna- 1950's & 1980's, Tlikakila River- 1950's & 1980's, Resurrection Creek- 1957 & 1977, Swentna River- 1930's & 1989, Willow Creek- 1930's & 1980's; Tustumena Lake 1950's & 1980's; Copper River area- 1920's & 1980's, and most of the northern portion of the Kenai National Wildlife Refuge (Holsten 1990). Type conversion did not occur in most of these areas during the early infestations because there were plenty of small, unsusceptible spruce remaining (Baker and Curtis 1972). It appears that many of these previously impacted stands became over-stocked and less thrifty with age and again became susceptible to spruce beetle outbreaks. Many of the repeatedly infested areas are undergoing a type conversion as little or no natural spruce regeneration is present (Holsten 1990).

Lake Clark National Park Resource Management specialists recently became aware of increased spruce beetle activity throughout the Tuxedni Bay Sitka spruce (P. sitchensis) stands located on the westside of the Kenai Peninsula. Likewise, Park Service personnel were also concerned with apparent increases in spruce beetle activity scattered throughout white spruce stands along the Tlikakila River drainage feeding Lake Clark. USDA Forest Health Management records (Holsten 1990) described an on-going spruce beetle outbreak in 1955 near Lake Clark. Extensive areas of previous beetle activity as well as current tree mortality were observed along the Tlikakila River, northeast of Lake Clark. The infestation was scattered over 100,000 acres in 1955 and declining. Spruce beetle activity remained low until 1984 when more than 31,000 acres of scattered (less than one infested tree/acre) spruce beetle caused tree mortality was observed once again throughout the Tlikakila River drainage. This beetle activity declined by 1985 (Holsten 1990). Scattered spruce beetle activity once again increased in this area in 1991-2 where 2,335 acres of scattered spruce beetle infested trees were detected (USDA 1992, 1993).

Forest Health Management personel undertook (June 21-24, 1993) a biological evaluation of spruce bark beetle infestations in the Lake Clark National Park. This biological evaluation was requested by Dr. Alan Bennet, Wildlife Biologist for the Lake Clark National Park.

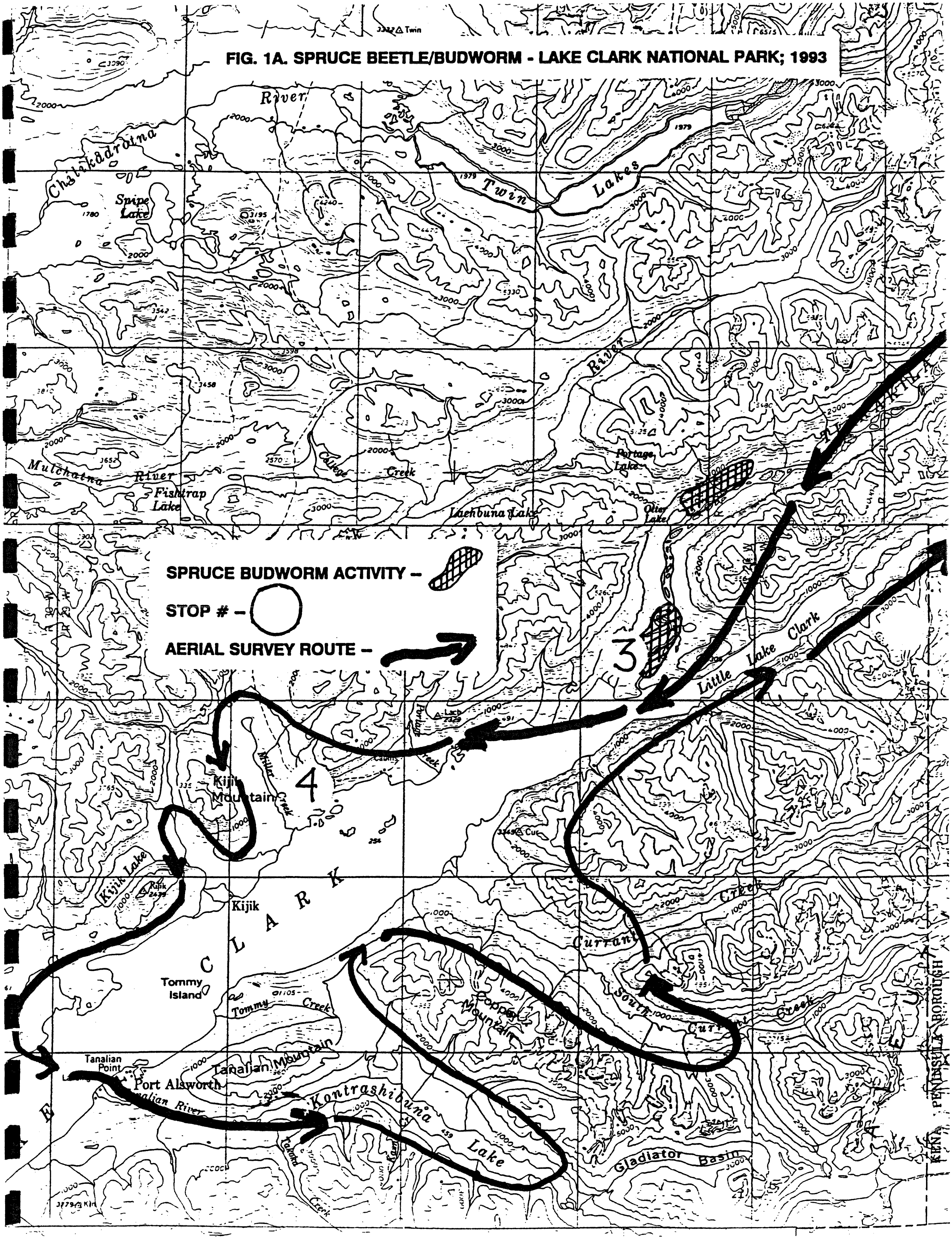
OBJECTIVE

Upon arrival at Park Headquaters, FHM personel met with Dr. Bennet to discuss his concerns and objectives for this evaluation. Dr. Bennet wanted four questions addressed: (1) What is the status (trend) of the apparent increase in spruce beetle activity near the headwaters of the Tlikakila River?; (2) Can we expect to see a spread of the infestation downstream towards Lake Clark?; (3) What is the risk of a spruce beetle outbreak in a few of the heavily stocked spruce stands bordering Lake Clark?; and (4) What is the risk of spruce beetle infestations to the other forested areas containing lesser quantities of spruce?

MATERIALS AND METHODS

FHM personel first conducted an aerial detection survey of the spruce beetle infested areas (Fig. 1 a,b,c) using a 206 Bell Jet Ranger. All on-going spruce beetle activity and any other observable forest health problems were mapped on 1:250,000 USGS Quandrangle maps. Areas of heavy spruce beetle activity and areas of light to no observable spruce beetle activity were selected for further ground truthing. In each of the four areas (Fig. 1) selected for ground truthing, multiple 1x10 chain (1 acre) transects were randomnly placed throughout the area. The purpose of these transects was to determine levels and trends of

FIG. 1A. SPRUCE BEETLE/BUDWORM - LAKE CLARK NATIONAL PARK; 1993



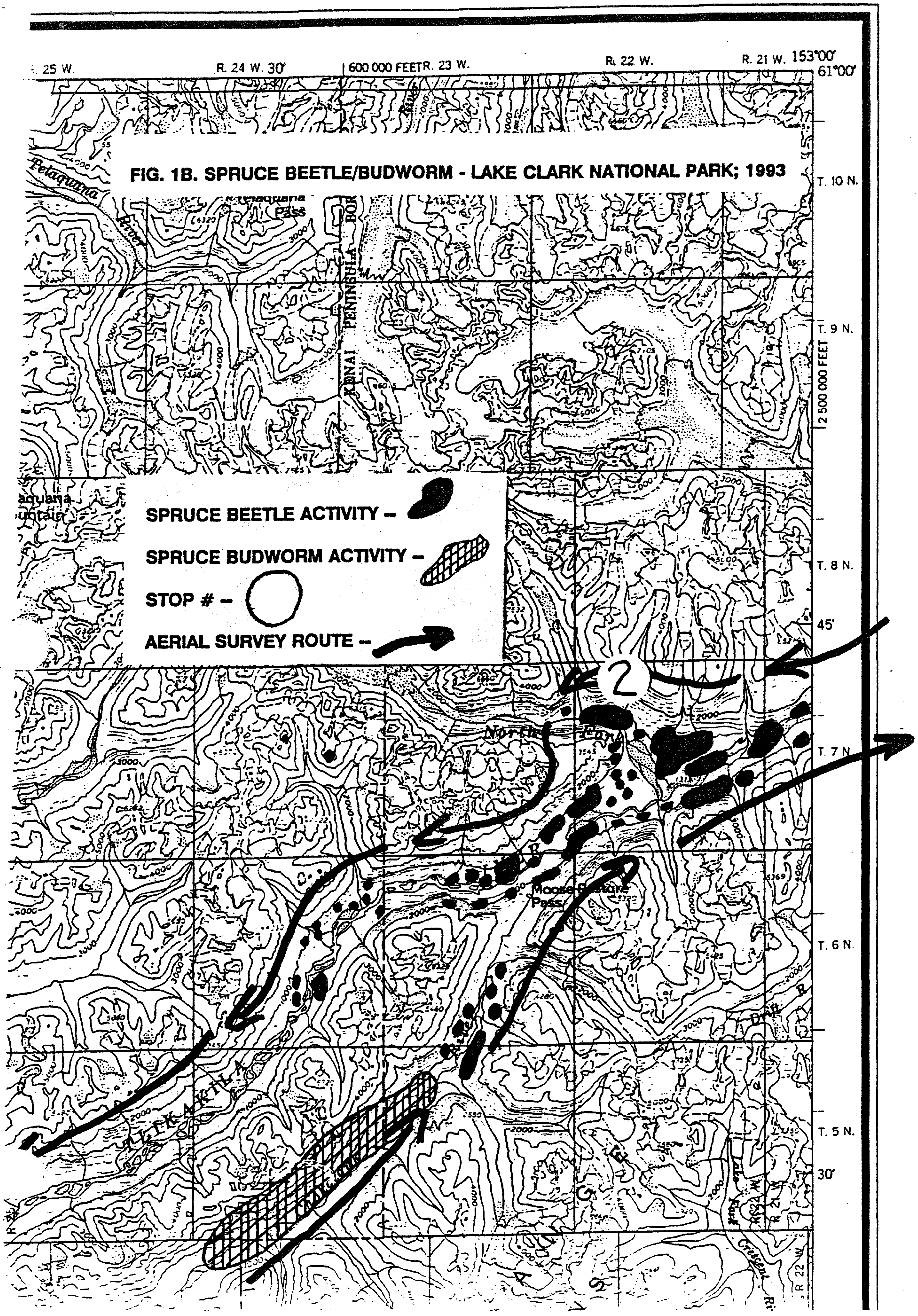
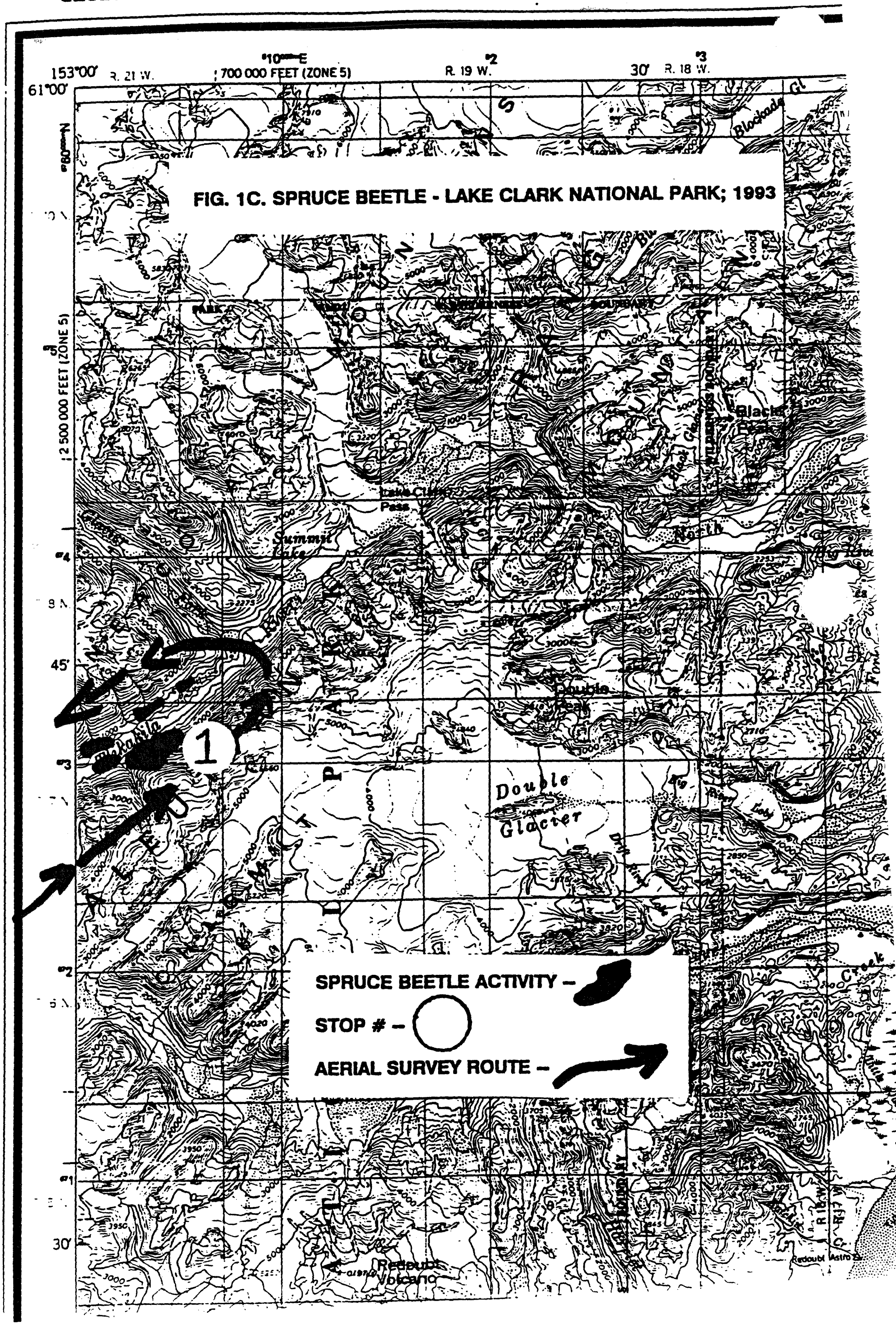


FIG. 1B. SPRUCE BEETLE/BUDWORM - LAKE CLARK NATIONAL PARK; 1993
SPRUCE BEETLE ACTIVITY --
SPRUCE BUDWORM ACTIVITY --
STOP # --
AERIAL SURVEY ROUTE --
2
R. 24 W.
R. 23 W.
R. 22 W.
R. 21 W.
153°00'
61°00'
600 000 FEET
T. 10 N.
T. 9 N.
2 500 000 FEET
T. 8 N.
45'
T. 7 N.
T. 6 N.
T. 5 N.
30'
KENAI PENINSULA BOR
Moose Pasture Pass

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY



spruce beetle activity. The following information was recorded from all spruce: (1) diameter at breast height (dbh), and (2) tree condition (unattacked [**Unatt**], 1993 pitch-out [**93 PO**][unsuccessful attack], 1993 successful attack [**93 At**], 1992 successful attack [**92 At**], and successful attacks occurring prior to 1992 [**> 92**], and other mortality [**Other**]). At the beginning of each chain-wide transect and every 5 chains thereafter, a 20 BAF variable prism plot was established in order to get a "feel" for general stand characteristics. For each "in" tree, the following information was recorded: (1) Tree species, dbh, and tree condition of the spruce component (e.g unattacked, 1993 pitch-out, 1993 new attacks, 1992 attacks, successful attacks occurring before 1992, and tree mortality due to other causes). If possible, total height and tree age were measured from two dominant or co-dominant spruce.

RESULTS AND DISCUSSION

Results of the aerial survey noted heavy spruce beetle activity (3,600 acres) along the Tlikakila River southwest of Glacier Fork and near the confluence of North Fork and Tlikakila Rivers (Fig. 1b). There was light, scattered spruce beetle activity northeast of Little Lake Clark along the Chakotonk River (Fig. 1). Four areas (Fig. 1) were selected for ground truthing: **STOP 1**--southwest of Glacier Fork Area, heavy spruce beetle activity (Fig. 1c); **STOP 2**--North Fork Area, heavy spruce beetle activity and two areas with little observable spruce beetle activity (Fig. 1b); **STOP 3**--near the outlet of the Tlilakila River (Fig. 1a), and **STOP 4** near the outlet of Miller Creek (Fig. 1a).

One additional observation from the aerial survey was the heavy defoliation of white spruce along the lower stretches of the Chakatonk and Tlikakila Rivers (Fig. 1 a,b). A ground check revealed the defoliation was due to heavy feeding of a species of spruce budworm, probably <u>Choristonuera</u> <u>orae</u>. There is little information concerning past budworm activity in Alaska. An outbreak on Sitka spruce was recorded in 1948 from Mile 0 to 59 on the Haines Highway; the species was tentatively identified as <u>C</u>. <u>fumiferana</u> (Holsten 1980). This identification was later changed to <u>C</u>. <u>orae</u>. Ground surveys detected significant budworm defoliation to white and Lutz spruce in many Anchorage residential and park areas. Since then, sporadic defoliation has been observed from Sitka spruce near Haines, to the white spruce stands of interior Alaska. Budworm populations increased dramatically in 1992 in interior Alaska. Aerial detection surveys noted more than 160,000 acres of defoliated spruce; mostly along the Tanana and Yukon Rivers and along the Nenana Ridge and throughout the Goldstream Valley near Fairbanks (USDA 1993). Impact studies conducted by research entomologists at the Institute of Northern Forestry have shown decreased diameter growth of defoliated spruce. There is concern that these budworm defoliated trees are stressed and as such are increasingly more susceptible to bark beetle attack and subsequent tree mortality.

Coniferous trees such a spruce with several age-classes of foliage suffer more severe defoliation than deciduous trees (Christiansen and Fjone 1993). Deciduous trees can rapidly replace the loss, sometimes within the same growing season. Spruce trees, on the other hand, normally retain their foliage for some 10 years and are much more impacted. If the budworm defoliation noted along the lower stretches of the Chakatonk and Tlikakila Rivers continues for consecutive years, these affected stands may become highly susceptible to spruce beetle infestations. A brief description of budworm life cycle is presented in Appendix B.

SPRUCE BEETLE GROUND TRUTHING:

STOP 1: Some of the heaviest spruce beetle activity has ocurred near the confluence of North Fork and Tlikakila River. Stands in this area are comprised mostly of white spruce. These are not overstocked stands as total basal area averages 80 sq. ft./acre; 78 sq. ft. being spruce (Table 1c).

Table 1a. Stop 1--tree condition of spruce by diameter class; figures are on a per acre basis (average of 3-1x10 chain strip cruises).

DBH	Unatt		93 PO		93 At		92 At		> 92		Other		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
2-3.9	5	88									.66	12	5.7	5
4-5.9	9	8									1.3	13	10.3	10
6-7.9	8	83			.4	3			.7	7	.7	7	9.7	9
8-9.9	11.3	72	.7	4	.33	2			1.7	11	1.7	11	15.6	15
10-11.9	6.7	46	1.3	9	2	14			3.7	26	.7	5	14.3	14
12-13.9	5	35	2.3	16	1	7	.3	2	5.3	38	.3	2	14.3	14
14-15.9	3	21	3	21	1.3	10	1.3	10	5	36	.3	2	14.0	14
16-17.9	1.3	14			1	11	.3	4	6.3	67	.3	4	9.3	9
> 18	.3	3			.7	6	1.3	13	8	78			10.3	10
TOTAL	49.7	--	7.3	--	6.7	--	3.3	--	30.6	--	6.0	--	103.5	--

There is a small component of cottonwood (<u>Populus trichocarpa</u>) and paper birch (<u>Betula papyrifera</u>) in the overstory. The understory is comprised of dense alder (<u>Alnus</u> sp.) and willow (<u>Salix</u> sp.). Average age and height of dominant and co-dominant spruce are 98 years and 65.5 feet, respectively. There are

approximately 104 spruce/acre based on the chain wide transects of which 50% remain unattacked (Table 1a) Thirty percent of the spruce were attacked and killed prior to 1992, with 5% being successfully attacked in 1992 and another 5% attacked and killed in 1993. An additional 8% of the trees were unsuccessfully attacked in 1993. Average spruce diameter (both live and dead) is 11.4"; average diameter of live, unattacked spruce is significantly less (8.7"), demonstrating spruce beetles preference for larger diameter trees (Table 1a). Spruce beetle activity will continue for a few years, then decline as the majority of the susceptible large diameter trees become infested and die.

Table 1b. Stop 1--tree condition by diameter class based on 20 BAF variable prism plot (average of 5 variable prism plots).

DBH	Unatt		93 PO		93 At		92 At		> 92		Other		Total	
2-3.9	n	%	n	%	n	%	n	%	n	%	n	%	n	%
											.2	100	.2	3
4-5.9	.4	99											.4	5
6-7.9	1	99											1	14
8-9.9	1	99											1	14
10-11.9	.4	50			.2	25			.2	25			.8	11
12-13.9	.8	44	.4	22			.2	12	.4	22			1.8	23
14-15.9	.4	50	.2	25					.2	25			.8	11
16-17.9					.2	20	.2	20	.6	60			1	14
> 18									.4	100			.4	5
TOTAL	4	–	.6	–	.4	–	.4	–	1.8	–	.2	–	7.4	–

Age and height of the dominant and co-dominant spruce indicate a relatively thrifty stand; normally resistant to spruce beetle outbreaks. A number of small (3-5 trees) scattered pockets of old blowdown were observed throughout the study. Such material is highly productive as breeding sites for spruce beetles. Undoubtedly, endemic spruce beetle populations availed themselves with this favorable breeding material. As this down material was utilized and as spruce beetle populations increased, standing trees became attacked; an infestation was initiated.

STOP 2: Stop 2 was located in the North Fork area (Fig. 1b). Spruce stands in this area are more heavily stocked than in Stop 1: average total basal area is 155 sq. ft./acre with spruce comprising 135 sq.ft/acre with approximately 192

trees per acre. The remainder of the stand is composed of cottonwood and paper birch (Table 2a,b).

Table 2a. Stop 2--tree condition of spruce by diameter class; figures are on a per acre basis (average of 2-1x10 chain strip cruises).

DBH	Unatt		93 PO		93 At		92 At		> 92		Other		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
2-3.9	16.5	94									1	6	17.5	9.1
4-5.9	31	94	.5	1	1	3			.5	1	.5	1	33.5	17.4
6-7.9	31.5	69	2.5	5	5	11			4.5	10	2.5	5	46	24
8-9.9	20.5	57	1	3	10	27	.5	1	4	11	.5	1	36.5	19
10-11.9	6	25	2	8	8	33	1.5	6	6	24	1	4	24.5	12.8
12-13.9	5	28	.5	3	6	33			6.5	36			18	9.4
14-15.9			1	10	3.5	33	.5	5	4.5	42	1	10	10.5	5.5
16-17.9									4	89	.5	11	4.5	2.3
> 18									1	100			1	.5
TOTAL	110.5	–	7.5	–	33	–	2.5	–	31	–	7	–	192	–

Table 2b. Stop 2--tree condition by diameter class based on 20 BAF variable prism plot (average of 4 prism plots).

DBH	Unatt		93 PO		93 At		92 At		> 92		Other		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
2-3.9	1.3	99											1.3	11.4
4-5.9	1.8	99											1.8	15.9
6-7.9	1.8		.25						.25				2.3	20.8
8-9.9	.5				.8								1.3	11.4
10-11.9	1.3				.3				.5				2.0	18
12-13.9	.5		.25						.25				1.0	9
14-15.9					.3				.75				1.0	9
16-17.9									.50				0.5	4.5
> 18														
TOTAL	7	–	0.5	–	1.3	–	0	–	2.3	–	0	–	11	–

Average age and height of dominant and co-dominant spruce are 115 years and 65.5 feet, respectively. Approximately 58% of the spruce are unattacked; similar to Stop 1. However, the infestation in this area appears to be of a more recent origin as only 16% of the spruce were killed prior to 1992 vs. 30% for Stop 1. The heaviest period of attack was in 1993, with approximately 17% of the spruce growing stock successfully attacked (Table 2a). Average diameter of both live and dead spruce is 8.5", significantly less than Stop 1 (11.4"). The diameter of live spruce averages 6.7"; a size normally not attacked. Similar to Stop 1, spruce beetle activity should continue for a few more years but should decline as spruce beetle populations are normally not sustained in stands with average diameters of 6" or less. Smaller diameter spruce are usually younger spruce and as such are thrifty with vigorous defense mechanisms allowing them to repel beetle attacks. Similar to Stop 1, there are small patches of old blowdown which could have increased spruce beetle populations to levels where standing trees became attacked.

STOP 3: Ground surveys were undertaken in spruce stands located near the outlet of Tlikakila River (Fig. 1a). Aerial surveys detected little or no spruce beetle activity. These stands are heavily stocked: total basal area averages 216 sq. ft/acre of which 200 sq. ft is comprised of spruce. Average age and height of dominant and co-dominant spruce

years and 70′, respectively. Average diameter of all spruce, both live and dead, is 10.5"; the live spruce component averages 10.9". The majority (67%) of the spruce killed by unknown causes occurred in the smaller diameter classes. This stand, due to its relatively high basal area and stocking, and average stand diameter is of high risk for increased spruce beetle activity.

Table 3a. Stop 3--tree condition of spruce by diameter class; figures are on a per acre basis (average of 2-1x10 chain strip cruises).

DBH	Unatt		93 PO		93 At		92 At		> 92		Other		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
2-3.9	3.5	82									2	18	5.5	2
4-5.9	7	70									3	30	10	4
6-7.9	22	76			.5	2			1	3	5.5	19	29	12
8-9.9	48	84	.5	1	.5	1			2.5	4	5.5	10	57	26
10-11.9	51	92			1	2			1.5	3	1.5	3	55	23
12-13.9	41.5	93	.5	1	1	2			1.5	3	.5	1	45	19
14-15.9	23	96			.5	2			.5	2			24	10
16-17.9	5.5	85									1	15	6.5	3
> 18	3	86			.5	14							3.5	1
TOTAL	204	–	1	–	4.0	–			7.0	–	19	–	235	

Table 3b. Stop 3--tree condition by diameter class based on 20 BAF variable prism plot (average of 5 prism plots).

DBH	Unatt		93 PO		93 At		92 At		> 92		Other		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
2-3.9	.2	50									.2	50	.4	4
4-5.9	.6	75									.2	25	.8	8
6-7.9	2.4	92									.2	8	2.6	25
8-9.9	3.2	99											3.2	29
10-11.9	1	99											1	10
12-13.9	.8	80			.2	20							1	10
14-15.9	.4	67							.2	33			.6	6
16-17.9	.4	99											.4	4
> 18	.4	99											.4	4
TOTAL	9.4	–			.2	–			.2	–	.6	–	10	–

STOP 4: Two chain-wide strip cruises and five variable prism plots were randomly placed in a spruce stand near the confluence of Miller Creek and Lake Clark (Fig. 1a). This stand was selected for ground truthing as the aerial survey detected little observable spruce beetle activity and from the air, the stand appeared to be susceptible to spruce beetle infestation due to high spruce stocking and susceptible diameter classes. Average total basal area is 172 sq. ft/acre of which 140 sq. ft. is comprised of spruce; the remainder being paper birch. There are approximately 333 spruce (> 2" dbh) per acre (Tables 4a, b). Average age and height of dominant and co-dominant spruce are 150 years and 58 feet, respectively. Very little spruce beetle activity was detected in this stand; 1% of the spruce had been killed prior to 1992. Another 5% of the spruce, mostly in the smaller diameter classes, had been killed by unknown causes. No new attacks were observed. Average diameter of the standing spruce is 6.7"; diameter classes usually not susceptible to spruce betle infestations. The overall risk of spruce beetle infestation in this stand is low due to the small size of the standing spruce.

Table 4a. Stop 4--tree condition of spruce by diameter class; figures are on a per acre basis (average of 2-1x10 chain strip cruises).

DBH	Unatt		93 PO		93 At		92 At		> 92		Other		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
2-3.9	44	89									5.5	11	49	15
4-5.9	98	96									4	4	102	29
6-7.9	85	94							.50	1	4.5	5	90	27
8-9.9	50	92							1.5	3	2.5	5	54	16
10-11.9	28	98									.5	2	29	9
12-13.9	8	94							.5	6			8.5	3
14-15.9														
16-17.9	1.5	100											1.5	1
> 18														
TOTAL	314	–							2.5	–	17	–	333	–

Table 4b. Stop 4--tree condition by diameter class based on 20 variable prism plot (average of 5 prism plots).

DBH	Unatt		93 PO		93 At		92 At		> 92		Other		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
2-3.9	.8	100											.80	8
4-5.9	1.4	100											1.4	15
6-7.9	1.4	78									.40	22	1.8	19
8-9.9	2.0	100											2.0	20
10-11.9	1.6	100											1.6	17
12-13.9	1.4	100											1.4	15
14-15.9														
16-17.9	.60	100											.60	6
> 18														
TOTAL	9.2	–									.40	–	9.6	–

SUMMARY AND CONCLUSIONS:

It appears that most of the recent spruce beetle activity first occurred near **Stop 1** as 30% of the spruce were killed prior to 1992. As of 1993, approximately 50% of the spruce have been attacked and killed. Beetle activity should continue in this area for a few more years until susceptible host material (spruce > 6" dbh) is depleted. Spruce beetle activity near **Stop 2** appears to be of more recent origin as only 16% of the spruce were killed before 1992. Increased spruce beetle activity in this area could be a result of scattered blowdown resulting in higher beetle populations as well as immigration of beetles from up the river, near Stop 1. Apparently, prevailing winds are from Lake Clark Pass down to the Lake. Spruce beetles are capable of flying 7 miles or longer if aided by wind. Spruce beetle activity will continue for a number of years before declining. A higher percentage of spruce will be killed in the spruce stands of Stop 1 than Stop 2 due to the higher percentage of large diameter spruce (Tables 1a, 2a). Approximately 50% of the spruce in the area of Stop 2 are less than 8" in diameter; size classes not normally infested.

Stands near the confluence of the Tlikakila River and Lake Clark (**Stop 3**), although currently only lightly infested (2%), are of high risk to spruce beetle infestation due to the relatively high stocking and high percentage (82%) of susceptible spruce diameter classes (> 8") (Table 3a). If some large scale forest disturbance, such as blowdown, occurs, beetle populations could rapidly increase to damaging levels.

The spruce stand near the confluence of Miller Creek and Lake Clark (**Stop 4**), even though both have relatively high stocking levels of spruce, are relatively resistent to heavy spruce beetle caused tree mortality due to the small average spruce diameter of the stand, 6.7". However, as these stands mature and average stand diameter increases, susceptibility will likewise increase.

The remaining forested areas surrounding Lake Clark are of low to medium risk to spruce beetle outbreaks. As previously mentioned, black spruce is rarely attacked; thus, the extensive black spruce stands are of low risk. Many of the forested areas contain a high percentage of hardwoods; birch, cottonwood, etc. Such stands are of low-medium risk, depending upon the percentage of large diameter spruce which comprise the overstory.

Aerial surveys did not detect spruce beetle activity along the shores of Kontrashibuna Lake or throughout the Currant Creek drainages.

There is no doubt that there are a myriad of impacts occurring to the beetle infested spruce ecosystems in the Lake Clark area. The impacts can be viewed positively or negatively depending upon the forest resources in question. Some of the impacts associated

with spruce beetle infestations include, but are not limited to:

(1) **Loss of merchantable value of killed trees:** The value of a spruce as sawtimber is reduced within three years of attack as weather checking and increased sap-rots occur. The value of a beetle killed tree as houselogs, chips, or firewood continues for some time.

(2) **Long term stand conversion:** To optimally regenerate both spruce and birch a site disturbance (i.e. fire, windthrow, flooding, etc) is required which results in a seed bed comprised of bare mineral soil with some organic material mixed in. If there is adequate seed source, such site disturbances provide excellent sites for regeneration. However, what is occurring on many sites in south-central Alaska after spruce beetles have opened up the canopy is that there is a paucity of regeneration coming in as there as been minimal site disturbance. Under such conditions, grass and other competing vegetation can quickly invade the site and prevent future colonization by tree species.

(3) **Impacts to wildlife habitat:** Those wildlife species that are dependent on large diameter, closed canopy spruce stands are negatively impacted. Those species that benefit from early successional stage vegetation will benefit from spruce beetle infestations as stand composition changes. Which species benefits will depend on the amount of site disturbance. Without a site disturbance, grasses and some shrubs will invade and occupy the site. Those wildlife species, such as voles, that benefit from grassy cover will thrive. On the other hand, if fire or some other site impacting factor occurs after the spruce beetles have impacted the overstory, a seed bed will be created which can allow for adequate regeneration of spruce and birch. Wildlife species that benefit from early seral vegetation, such as birch and willow sprouts, will benefit.

(4) **Impact to scenic quality:** Recent studies (Daniel et. al 1992) have demonstrated that there is a significant decline in scenic quality of spruce beetle impacted stands and that scenic beauty is an important resource on the Chugach National Forest. Along scenic corridors, maintaining or enhancing scenic quality necessitates minimizing impacts from spruce beetle infestations.

(5) **Fire hazard:** There is concern that fire hazard of spruce beetle impacted stands will increase over time as dead trees fall, dry grass accumulates, thus increasing fuel loading.

(6) **Impact to fisheries:** If salmon spawning streams are bordered by large diameter spruce and if these trees are subsequently killed by spruce beetles, there is concern as to the availability of large woody debris. A continual

supply of large woody debris in spawning streams is a necessary component for the integrity of spawning habitat.

There are a variety of techniques that can be used to prevent, mitigate, or reduce impacts associated with spruce beetle infestations. However, before pest management prescriptions can be developed, the resource objective(s) for a particular stand, watershed, landscape, etc. must be determined. The forest manager must evaluate the resource values and economics of management actions for each stand in light of management objectives. The beetle population level must also be considered because population levels will determine the priority of management actions and the type of strategy to be invoked.

The primary strategy should be silvicultural treatments of potentially susceptible stands in order to maintain their health with a moderate growth rate (Hard and Holsten 1985). The first step in this strategy is to hazard/risk rate spruce stands, which will indicate the most susceptible stands. Forest Health Management, in cooperation with Institute of Northern Forestry, has recently developed a PC compatible spruce beetle expert system (Reynolds and Holsten 1992). One of the functions of this knowlege base system is the hazard and risk rating of spruce stands in south-central Alaska. Hazard is defined as the amount of spruce basal area killed within ten years if you have an outbreak. Risk is defined as the probability of having an outbreak and is dependent on stand structure, spruce beetle breeding material, and spruce beetle population dynamics. The stands can then be treated with harvesting directed at the most susceptible stands. This strategy assumes beetle populatons are not immediately threathening resource values. If they are, suppression measures are more appropriate.

Suppression measures which include silvicultural, physical, and chemical methods are available. Some measures are suitable only for populations in windthrown host material; other methods are better suited for infestations in standing trees. Most suppression methods, however, are short-term responses to beetle populations. They correct only the immediate situation and are not long lasting.

Pest management techniques include, but are not limited to (Holsten et. al 1991):

(1) **Sanitation overstory removal** involves the removal of all infested and susceptible spruce and using harvesting and site preparation techniques that encourage regeneration of a new, vigorous stand.

(2) **Sanitation partial** cut involves the removal of infested and susceptible spruce to improve the growth and thus the vigor of the residual stand. In essence, this is a thinning from above.

(3) **Trap trees** are large diameter uninfested spruce that are felled in a shady location before beetle flight. Trap trees can absorb up to 10 times the number of spruce beetles that a standing tree will absorb. Spruce beetle preferentially attack downed over standing trees. Once infested, trap trees should be removed from the forest or treated chemically, with fire, or debarked. Trap trees are an effective control when spruce beetle populations are building in standing trees. Ratios of trap trees to infested standing trees range from 1:2 to 1:10.

(4) **Fire** involves piling and burning infested logging residuals and windthrow to destroy spruce beetle brood. Only the bark has to be scorched to destroy the insects.

(5) **Insecticides** such as carbaryl and lindane are registered by the E.P.A. for the prevention of spruce beetle attacks. Formulations of these insecticides are applied to the boles of uninfested high valued trees to kill attacking adult beetles.

(6) **Pheromones** are chemical substances that influence insect behavior. Currently, the use of synthetic attractants and the anti-aggregating pheromone show promise; especially in discouraging spruce beetles from attacking standing trees. However, these compounds are still experimental and have not been registered for use by the E.P.A. They can be used, however, in a small-scale, research context.

As previously mentioned, once resource objectives for a particular stand are defined, Forest Health prescriptions can be developed to minimize spruce beetle impacts to the resources in question. The key to managing the spruce beetle is to reduce tree mortality and associated impacts to acceptable levels which vary with the goals and objectives of the land manager for specific areas. Forest health management presciptions must be developed that consider a wide range of management and land use values. Five major premises are applicable to spruce beetles in Alaska (State of Alaska 1992):

1. All hosts, plant associations, etc., regardless of ownership, can be classified into land classification units (see below).

2. Spruce beetles **cannot** be eradicated over extensive areas.

3. Management of spruce beetles is viable in those areas that have resources with relatively high values.

4. The optimal strategy for managing the spruce beetle is to intensively manage the host type; thus preventing outbreaks.

5. Prevention is possible in moderate to highly susceptible stands, or in low susceptible stands which will be in a

moderate to high susceptible condition in the near future.

Failure to recognize the above five points will lead to failure for any long range management of spruce beetles.

A procedure has been developed to match management strategies to a land classification system (Freeling and Seaver 1980). The land classification system is based on the following criteria:

(1) SPRUCE BEETLE RISK: As previously mentioned, Forest Health Management has developed a Hazard and Risk model for spruce beetles in south-central Alaska (Reynolds and Holsten 1992). Stands are ranked low or moderate to high.

(2) ACCESSIBILITY AND/OR OPERABILITY: These criteria vary with the management strategy selected and the equipment available to implement the strategy. For example, slopes > 40% may be inoperable and inaccessible for conventional logging equipment but operable for a high lead system or appropriate for chemical or trap tree treatment. Stands are assessed as accessible and/or operable or inaccessible and/or inoperable.

(3) TREE/RESOURCE VALUE: Value systems are highly variable and often difficult to quantify. The management goals and objectives for an area determine the value system to be used. Effects (impacts) of the spruce beetle may detract or enhance that value. The objective is to minimize the loss of value from spruce beetle damage through the application of one or more strategies. Tree/resource values are rated as low or high.

LAND CLASSIFICATION CATEGORIES:

A. Moderate to high SB risk
Accessible and/or operable
High resource value

B. Moderate to high SB risk
Access. and/or operable
Low resource value

C. Moderate to high SB risk
Inaccess. and/or inoper.
High resource value

D. Moderate to high SB risk
Inaccess. and/or inoper.
Low resource value

E. Low SB risk
Accessible and/or operable
High resoure value

F. Low SB risk
Access. and/or operable
Low resoure value

G. Low SB risk
Inaccess. and/or inoper.
High resource value

H. Low SB risk
Inaccess. and/or inoper.
Low resource value

MANAGEMENT STRATEGIES BY LAND CLASSIFICATION:

LAND CLASSIFICATION A: In developed recreation sites such as campgrounds and trailheads where spruce beetle is present, suppress insect populations by removing infested trees before beetle flight. The use of chemical tools may be warranted. If an epidemic has not yet occurred, thinning, combined with a trap tree program, may be the best alternative. In Type A areas other than developed recreation sites, thinning is the preferred strategy followed by harvesting infested trees. A rule-of-thumb is if the recreation value is greater than about six times the stumpage value on a per acre basis, then suppression is warranted. Thinning is the preferred strategy. Immediate thinning is preferred to waiting for an epidemic to start then thinning.

LAND CLASSIFICATION B: A thinning program is the preferred strategy in these areas due to the beneficial effects and reduced negative impacts on recreation.

LAND CLASSIFICATION C: In areas where thinning is impractical due to lack of accessibility, such as a remote cabin site, chemical tools are considered best strategy under epidemic conditions. However, this strategy may be only marginally acceptable to doing nothing and accepting the losses depending upon public involvement.

LAND CLASSIFICATION E: Harvesting infested trees is the preferred strategy on low risk areas. Because these are high resource areas, this strategy is effective in reducing the impacts on scenic, recreational and real-estate values.

LAND CLASSIFICATION D,F,G, AND H: Allow the beetle to run its course.

Forest Health Management recommends that a resource planning effort be initiated to establish resource objectives (i.e. desired future stand conditions) for the Lake Clark National Park area. Once resource objectives for a particular watershed, stand, etc. have been established, site specific forest health prescriptions can be developed. Forest health prescriptions consider preventive, suppression, and restoration techniques for managing spruce beetle habitat.

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APPENDIX A

SPRUCE BEETLE

Dendroctonus rufipennis (Kirby)

HOSTS: White, Sitka, Lutz, and black spruce.

DISTRIBUTION: Wherever spruce is found; a serious forest pest in south-central Alaska throughout Cook Inlet and Kenai Peninsula regions.

DAMAGE: Larvae feed beneath bark, usually killing affected trees.

DESCRIPTION: Adult spruce beetles are maroon to black; cylindrical in shape, approximately 5 mm long and 3 mm wide. Larvae are stout, white, legless grubs, 6 mm long when full-grown. The pupae are soft-bodied, white, and have some adult features.

BIOLOGY: The life cycle of the spruce beetle may vary from one to three years, with a two-year cycle being the most common. Temperature plays an important part in determining the length of time required for beetle development.

Adult beetles become active in the spring (late May-early June) when air temperatures reach a threshold of 16o C (61 F). At this time, beetles emerge from trees in which they overwintered and fly in search of new host material. These dispersal flights may be short-range even though beetles are capable of flying for several miles without stopping.

Spruce beetles prefer to attack the sides and bottom surfaces of windthrown or other downed materials which have been on the ground less than one year. In the absence of such host material, large-diameter live trees may be attacked instead, and if beetle populations are high, these trees may be killed.

Beetle attacks, whether on windthrown or on standing timber, are mediated by pheromones which insure that individual trees will be attacked "en masse", and fully colonized by subsequent broods. Trees that are mass-attacked form attractive centers which result in groups of trees being killed by spillover attacks.

Female beetles initiate attacks and begin constructing an egg gallery in the cambium parallel to the gain of the tree. They are joined by males and after mating, lay eggs in small niches along the sides of the egg gallery. Most eggs will hatch by August.

As they feed in the cambium, larvae construct their own galleries perpendicular to the egg gallery. Normally, spruce beetles pass

the first winter in the larval stage, resume feeding the next spring, and pupate by summer. About two weeks later, pupae transform into adults which pass the second winter, either in the old pupation site, or more commonly, in the bases of infested trees. The following spring, two years after initial attack, the new adults emerge and attack new host material, in some years when temperatures are abnormally high, or on certain warmer microsites, spruce beetles may complete their development within one season and new adults will emerge one year after attack.

Most major outbreaks of spruce beetle have originated from stand disturbances-blowdown, logging, or right-of-way clearance. Stand susceptibility to beetle attack is influenced by stocking, with slow growth and moisture stress playing an important part in predisposing trees to attack.

APPENDIX B

SPRUCE BUDWORM

Choristoneura spp.

HOST: Sitka, Lutz, and white spruce.

DISTRIBUTION: Throughout Alaska. Populations have been found as far north as Fairbanks.

DAMAGE: Larvae destroy buds, foliage, cones and seeds. Heavy defoliation can result in growth loss and increase susceptible to other insects, such as bark beetles.

DESCRIPTION: Adults are predominantly grey-brown moths and have a wingspread of 22 to 28 mm. Eggs are light green and are laid in shinglelike masses on the underside of needles. Mature larvae are approximately 32 mm long, with brownish head and body and prominent ivory-colored spots.

BIOLOGY: Depending on the species, can have a 1-year or 2-year life cycle. With a 1-year life cycle, the budworm overwinters as larvae in silken shelters beneath bark scales and old male flowers. Larvae enter and feed upon buds in May or June, then asttack new foliage. Larvae mature in early July; pupae are located in webbed new foliage. New adults appear a week or so later and are commonly seen hovering around infested trees during evening hours. Eggs are deposited in shinglelike masses on the underside of needles. Recently emerged larvae migrate to overwintering sites.